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EXPERIMENTS ON THE PROCESSING AND STORING OF DEGLET NOOR DATES IN CALIFORNIA

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INTRODUCTION

The storage of California dates over considerable periods to permit the orderly marketing of the fruit has received little attention until recent years, and no extensive practical tests have been recorded on the behavior of these dates under various conditions of storage. The date industry in the Coachella Valley, Calif., is of comparatively recent origin, and until the last few years much of the crop has been marketed fresh as soon as harvested. However, with the rapid increase in production of the Deglet Noor date, a choice cane-sugar variety, it is desirable that some means be provided whereby the fruit may be harvested, processed, and stored in order that it may be marketed over a prolonged period without loss of its fine quality. This will assure better returns to the growers than can logically be expected if the old practice of marketing the crop within the comparatively short harvest period is continued. It may also relieve the demand for labor and space in the packing houses by extending the work of grading, packing, and shipping over a much longer period.

As a basis for working out practical methods of handling and storing Deglet Noor dates with a minimum loss of their characteristic

¹ The writers wish to make acknowledgment of the facilities provided for this work by the growers of Deglet Noor dates in the Coachella Valley, Calif. Besides the United States Experiment Date Garden at Indio, Calif., special mention is made of the Deglet Noor Date Growers' Association, Narbonne ranch, Cook ranch, and Cowgill-Conner Date Co., whose cooperation has been of great value. Reports on the progress of the work have been made from time to time to the growers at the annual meetings of the Date Growers' Institute.

qualities, an investigation was undertaken to study the behavior of this fruit under various conditions of storage. It was not the intention to make a thorough chemical study of the fruit, since this had already been done or undertaken by other investigators (12, 4),² but rather to obtain only such chemical data as would be useful in interpreting physical observations and in serving as a criterion of quality in the fruit. The moisture content and the percentage of reducing and total sugars proved to be valuable guides in formulating packing-house and storage practices.

Methods of picking the dates and the packing-house routine were studied in the field. Special attention was paid to the separation of the fruit into various lots based on the degree of maturity, and experiments were conducted on the processing of the fruit in these lots. The storage tests included studies on the behavior of the various lots under different storage conditions over periods ranging from 2 to 10 months.

THE DEGLET NOOR DATE INDUSTRY IN CALIFORNIA

The Deglet Noor date is produced in California largely in the Coachella Valley. Numerous other varieties have been planted, many of them mainly for experimental purposes.* Of the 15 or 20 varieties now grown in this valley from offshoots, only 4, namely, Zehedy, Khadrawy, Saidy, and Deglet Noor, have been planted to the extent of 1,000 trees or more. The Deglet Noor variety has been planted more extensively than all the others, the total number of trees set out in commercial gardens being estimated at more than 15,000. The harvested crop of this variety was estimated at 42,000 pounds in 1921, 107,000 pounds in 1922, 190,000 pounds in 1923, 400,000 pounds in 1924, 450,000 pounds in 1925 (when the crop was reduced by damage from rain), 625,000 pounds in 1926, 800,000 pounds in 1927, about 1,200,000 pounds in 1928, and more than 1,600,000 pounds in 1929. As new trees are coming into bearing every year, it is expected that there will be a steady increase in the annual production of this date for several years.

METHODS OF HANDLING THE CROP

The bearing Deglet Noor date palm has from 6 to 10 fruit clusters growing from near the terminal bud. Some date growers consider that from the standpoint of productiveness the ideal cluster consists, after pruning, of about 30 threads, each bearing about 30 dates. All growers, however, cut part of the Deglet Noor bunches off entirely or else prune all of them considerably.

The fruit does not ripen uniformly throughout the clusters nor upon a thread, and this necessitates picking over the entire garden at intervals of a few days to two weeks, depending on the weather. Fruit that is permitted to mature fully on the tree is lacking in uniformity, and a large proportion of it is of relatively poor keeping quality. In general the dates are not picked until they are hazel in color and have dried enough to show slight wrinkles of the skin. They are transported from the field in shallow boxes holding about 20 pounds, and after being fumigated under vacuum to kill insects

² Italic numbers in parenthesis refer to Literature Cited, p. 23.

and insect eggs, the dust and sand are removed by towels or by mechanical dry brushes, and the dates are sorted by hand into lots of uniform maturity. They are then processed under heat until the texture of the flesh, including the white portion, or "rag,"³ adjoining the seed, becomes soft and amber in color. This treatment also removes the astringency and causes the flesh to become somewhat translucent. After processing and further conditioning to reduce the moisture content, the dates are again sorted into grades according to texture, shape, and color, then packed and again fumigated under vacuum. The fancy grades are packed in 10-ounce and 1-pound boxes, and the standard grades in 3-pound, 5-pound, and 20-pound cartons.

CHARACTERISTICS OF DEGLET NOOR DATES

The ripening of Deglet Noor dates is accompanied by a gradual change of color of the skin from rose to amber, cinnamon, and finally to hazel; the flesh softens and the rag is gradually eliminated. The astringency of the immature dates, due to the presence of tannin, is gradually reduced, as the tannin is deposited in an insoluble, tasteless form. This occurs rather rapidly in picked fruit of fair maturity. It proceeds almost regardless of the temperature at which the fruit is held and appears to be fairly independent of the other major changes that take place during ripening. The ripening progresses from the tip of the fruit to the stem, and more rapidly near the skin than near the seed. The flesh at the shoulder (stem end) of the fruit adjoining the seed is the last part to take on the characteristics of the soft-ripe fruit, and the rose color of the skin around the opening at the stem end is the last to fade into the cinnamon or hazel color of the ripe skin. The amount of rag and the vividness of the color ring are indicators of the relative maturity. Coincident with the changes in color and texture and the disappearance of the astringency there take place a reduction in the moisture content and a gradual inversion of cane sugar to reducing sugar through the action of enzymes, but each reaction appears to be largely independent of the others.

Under normal conditions the several changes which take place as the fruit matures proceed fairly uniformly, but weather conditions before it is picked and the treatment to which it is later subjected frequently unbalance these processes, so that the several changes do not take place in normal relationship to one another. The change in the color of the skin may proceed faster than the softening of the flesh; the tannin may change to an insoluble, tasteless form before the fruit reaches the soft-ripe stage at which this usually takes place; and the inversion of cane sugar in the flesh near the skin and adjoining the seed may proceed far enough to cause sirup to form before the remainder of the flesh has materially softened. Such abnormal changes, however, do not generally occur in the regular commercial processing of the fruit.

Deterioration of quality in the date manifests itself in a number of ways. The skin may darken to an unattractive chestnut or mahogany color; there may be an excessive inversion of cane sugar,

³ The white, unsoftened, fibrous flesh of the Deglet Noor date is called "rag." The name is suggested by the stringy texture, particularly of that portion adjacent to the seed.

with the resultant formation of sirup; or the fruit may sour as a result of excess moisture. Coincident with any of the foregoing conditions there is usually complete loss of the characteristic flavor.

In order, therefore, to fulfill the requirements of the industry, the commercial storage of Deglet Noor dates must be so conducted as to prevent or reduce to a minimum the several types of deterioration referred to. To accomplish this, the sorting of the fruit according to its condition and stage of maturity and the processing of the several lots in strict accordance with the requirements are of prime importance. It is necessary, therefore, to understand thoroughly the behavior of the fruit under various conditions of handling and to study the relationship of its treatment in the packing house to its storage qualities. It was for this purpose that the investigations were undertaken.

EXPERIMENTAL WORK

As a basis for storage experiments undertaken, the fruit was sorted into a number of groups that appeared to represent definite changes of maturity, as indicated by certain characteristics of color and texture. In some seasons the fruit sorted on the basis of physical characteristics does not entirely represent the same stages of maturity as fruit of similar lots in other seasons, but on the whole the relative differences between lots are fairly consistent and are a valuable aid in determining the characteristics that it must possess for successful storage. The colored illustrations⁴ of the dates shown in Plate 1 are representative of the several groups into which the fresh fruit was separated, and the characteristics of these groups are described in Table 1.

TABLE 1.—*Physical characteristics of Deglet Noor dates at various stages of maturity*

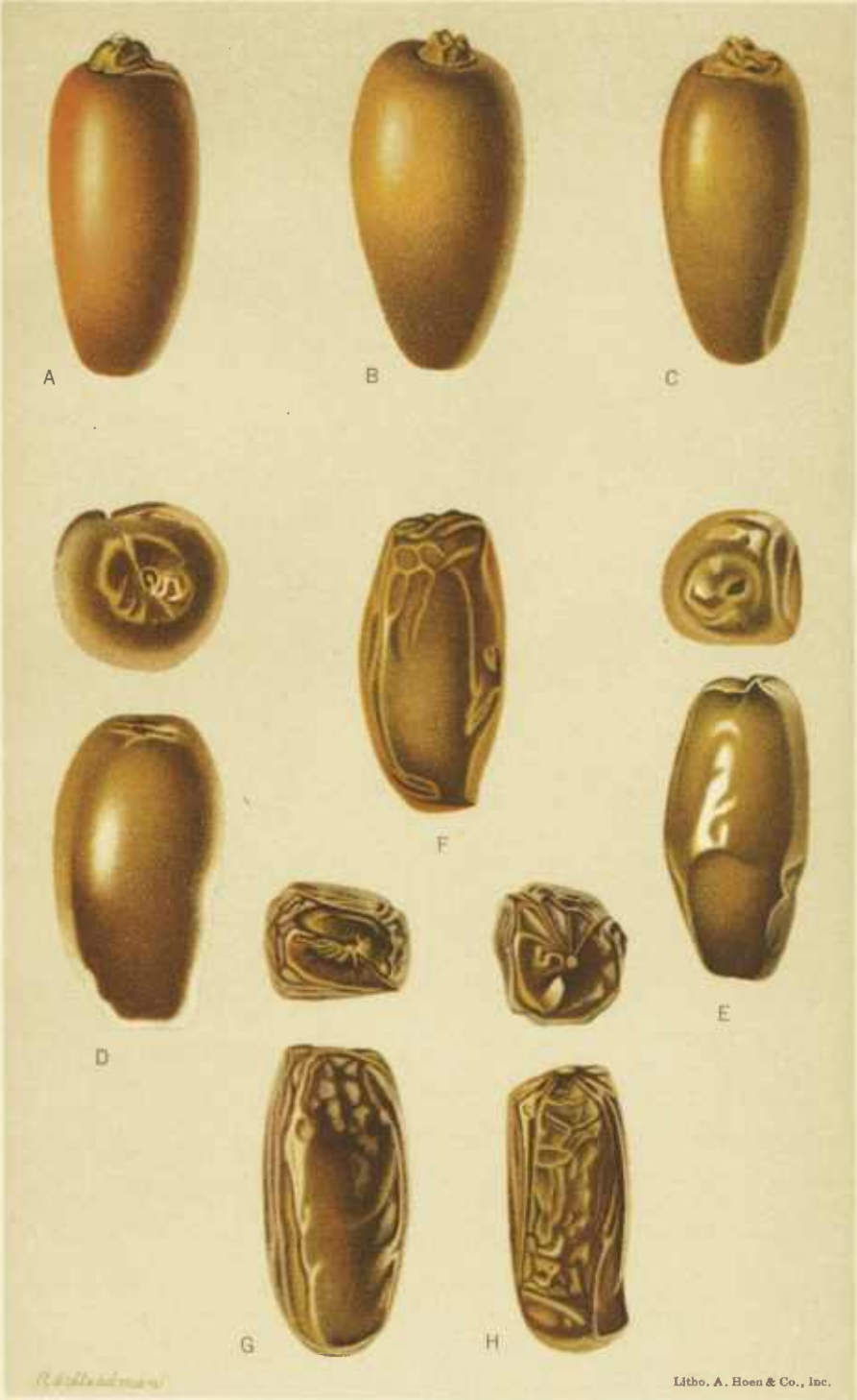
Designation of stage ^a	Tip half		Shoulder		Color of ring at stem end	Approximate amount of rag at shoulder (per cent)
	Color	Texture	Color	Texture		
A, full rose.....	Rose to amber	Hard to firm..	Rose.....	Hard.....	Rose.....	100.
B, half rose.....	Amber.....	Firm.....	do.....	do.....	do.....	100.
C, rose shoulder.	Amber to cinnamon.	Yielding.....	Pale rose..	Firm.....	do.....	100.
D, turning.....	Cinnamon to hazel.	Yielding to pliable.	Amber to cinnamon.	Yielding..	Pale rose to light brownish purple.	50 to 75. ^b
E, soft ripe.....	Hazel.....	Pliable to slightly soft; translucent.	Cinnamon to hazel.	Pliable....	No well-defined color.	None to 50.
F-G, ^c soft wrinkled.	Hazel to russet.	Pliable.....	Hazel.....	do.....	Some rose color, others no well-defined color.	None to 75.
H, semidry.....	do.....	Pliable to leathery.	Russet....	Pliable to leathery.	do.....	Do.

^a As a matter of convenience these terms will be used throughout this bulletin to designate fruit of the several stages of maturity.

^b Fruit in stages D to G has considerably more rag when picked in November than fruit of the same stages picked in September and early October.

^c In the stages F-G is included much fruit that dries on the tree before normal ripening takes place.

⁴ The colors were determined according to the following publication: RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., illus. Washington, D. C. 1912.



California-grown Deglet Noor dates at various stages of maturity. (Natural size.)
For a description of the fruit at these stages see Table 1

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METHODS OF SAMPLING AND ANALYSIS

Facilities for making the required chemical analyses of the dates were not available in the region where the dates were grown, and the samples to be analyzed were too numerous for all to be taken care of at the time the fruit was picked and processed. It was necessary, therefore, to prepare the samples in such a way that the analytical work could be done at the United States Horticultural Field Laboratory at Lamanda Park, Calif. During the harvest period of 1924 the processing rooms at the United States Experiment Date Garden at Indio were used for processing the fruit in the various experiments. For the two subsequent seasons processing rooms were built and equipped at the laboratory at Lamanda Park, which made it possible to bring the fruit directly from the field to the laboratory where the experiments could be conducted.

In preparing samples from any one lot for moisture and sugar determinations, approximately 1 pound of representative fruit was picked from the lot and the seeds were removed. The dates were then immediately passed twice through a common food chopper and the ground material was thoroughly mixed by means of a spatula or a thin-bladed knife. Thus prepared, it was used immediately for the several analyses.

MOISTURE DETERMINATIONS

On account of the high sugar content of dates, the quantitative removal of moisture from the ground material is rather difficult. Facilities for using an electric vacuum oven were not available for this work, therefore the moisture determinations during the first year's work could not be made according to the most approved method, but the samples were prepared in such a way that removal of the moisture could be accomplished fairly readily. Ten grams of the ground material was placed in a wide-mouthed bottle of 250 cubic centimeters capacity containing 175 cubic centimeters of 95 per cent alcohol. The contents were brought to a gentle boil in a water bath and maintained at that temperature for about 10 minutes. After the mass was thoroughly broken up, the bottle was securely closed with a rubber stopper. Later the alcoholic solution was carefully decanted into a weighed 250 cubic centimeter beaker, and the solid residue was washed into a weighed 150 cubic centimeter beaker with 95 per cent alcohol. The bottle was thoroughly rinsed several times with 95 per cent alcohol, and the rinsings were added to the first beaker. By this process most of the sugar is removed from the other solids and the evaporation of the water facilitated. Both beakers were placed on a water bath until most of the liquids were evaporated, and then they were kept overnight in an electric oven at a temperature not exceeding 90° C.

After the first year's work the moisture determinations were made by the Sterling-Bidwell method (1). By this method the moisture can be determined with reasonable accuracy in about 1½ hours from the time the fruit is ready to be sampled, which makes it well adapted to rapid control work in the packing house.

SUGAR DETERMINATION

Samples for determining the direct reducing and total sugars were prepared as follows: 40 grams of the ground dates were weighed

on a small piece of thin paper and thus transferred to a pint fruit jar of the clamped-cover type containing 300 cubic centimeters of 80 per cent alcohol. About half a gram of calcium carbonate was added, and the contents were heated in a water bath to near the boiling point and maintained at that temperature for about 10 minutes. The mass of ground dates was then thoroughly broken up with a glass rod and the jar sealed. In this condition the samples were kept until the analyses could be undertaken. To proceed with the analysis the contents of the jar were again heated in a water bath to near the boiling point and the liquid was decanted into a 1,000 cubic centimeter volumetric flask. The solid matter remaining was thoroughly broken up and transferred to a 400 cubic centimeter beaker with about 200 cubic centimeters of 80 per cent alcohol and warmed gently to 60° C. After settling, the supernatant liquid was added to the contents of the flask and the solid residue thoroughly stirred and digested with about 150 cubic centimeters of distilled water at 60° for several minutes, after which the entire contents were transferred to the flask. The jar and the beaker were thoroughly rinsed with 80 per cent alcohol and the rinsings added to the flask. The contents of the latter were then made up to 1,000 cubic centimeters with 80 per cent alcohol, the whole was thoroughly mixed, and the flask was set aside, with occasional shaking for at least six days.

For the determination of the total and reducing sugars, 100 cubic centimeters of the filtered solution from the flask was transferred to a 250 cubic centimeter beaker, evaporated on a water bath to a small volume, and then transferred with about 200 cubic centimeters of hot water to a 250 cubic centimeter flask. The solution, after cooling, was clarified with lead-acetate solution, made up to volume with distilled water, filtered, the excess lead precipitated with dry sodium oxalate, and the solution again filtered. Fifty cubic centimeters of this filtrate was then transferred to a 250 cubic centimeter volumetric flask and made up to volume with distilled water. For the determination of direct reducing sugars, 25 cubic centimeters of this solution was used for reduction. For the total sugar determination, 50 cubic centimeters was transferred to a 100 cubic centimeter volumetric flask, 5 cubic centimeters of hydrochloric acid (specific gravity 1.178) added, and the solution allowed to stand overnight. The next morning the contents were made up to volume with distilled water, approximately neutralized with anhydrous sodium carbonate, and 25 cubic centimeters was used for reduction. The Munson and Walker method of reduction was used in all cases, and the copper was determined by Bertrand's permanganate method.

The direct reducing sugars in these dates resulted from the gradual inversion of the cane sugar on the tree or after picking. The percentages of total sugar reported, therefore, represent the percentage of reducing sugar plus the percentage of cane sugar present, calculated on the moisture-free basis.

EXAMINATION OF FRESH DATES

The first experiment undertaken was to determine the variation in moisture, reducing sugar, and total sugar content of fresh Deglet Noor dates produced in different localities in the valley. For this purpose dates were obtained from a number of gardens at several

periods during the harvest seasons of 1924, 1925, and 1926. The locations of these gardens are as follows: Garden S at Indio; K, 8 miles west of Indio; L, 8 miles south of Indio; N, 12 miles south of Indio near the foothills. Samples of fruit were also obtained from two adjoining trees at the United States Experiment Date Garden at Indio, which are designated G' and G''.

From 60 to 80 pounds of fruit was picked for each lot whenever it was available in such quantities. The fruit was thoroughly cleaned and separated into lots representing the several stages of maturity, according to the physical characteristics given in Table 1, and illustrated in Plate 1, and the moisture and sugar determinations were made, the results of which are given in Table 2. Some of this fruit was processed with moderate heat to obtain the desired color and texture and again examined with regard to moisture and sugar content. The results of these examinations are given in Table 4 and are discussed in a later section.

TABLE 2.—Percentage of moisture, reducing sugar, and total sugars¹ in freshly picked Deglet Noor dates from various sources and at various periods and stages of maturity during 1924, 1925, and 1926

Year and source	Stage of maturity ²	Date of picking	Moisture	Reducing sugar	Total sugar	Year and source	Stage of maturity ²	Date of picking	Moisture	Reducing sugar	Total sugar
1924			<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	1925			<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
S	B	Oct. 7	35.69	11.34	64.86	K	C	Oct. 2	35.43	12.34	74.43
	C	do	42.01	15.50	78.78		D-E	do	29.46	17.11	72.30
	D-E	do	39.98	20.09	84.89		F-G	do	24.96	18.50	73.35
K	F-G	do				N	C	do	36.22	14.25	75.83
	C	do	35.49	11.04	71.72		D-E	do	31.09	17.52	76.67
	D-E	do	34.54	13.91	76.68		F-G	do	25.77	19.68	76.55
G'	F-G	do	26.99	16.52	71.49	L	A	do	57.84	4.22	75.41
	C	do	37.46				B	do			
	D-E	do	36.59	13.12	79.61		C	do	37.28	15.48	75.35
G''	F-G	do	30.18	15.84	74.26	S	D-E	do	31.65	19.77	75.48
	C	do	37.49	10.84	72.63		F-G	do	29.08	21.25	75.34
	D-E	do	32.20	12.75	71.47	K	C	Oct. 20	39.20	11.13	76.23
S	F-G	do	27.07	16.22	71.74		D-E	do	34.35	12.82	74.80
	B	Oct. 21					F-G	do	30.74	13.68	74.06
	C	do	36.56	12.11	80.61	K	H	do			
K	D-E	do	34.35	16.42	80.04		C	do	38.49	11.93	72.62
	F-G	do	24.78	16.38	73.36		D-E	do	33.30	18.33	75.83
G'	C	do	37.60	12.54	78.13	N	F-G	do	29.51	18.88	73.83
	D-E	do	37.14	18.93	85.92		C	do	38.44	11.66	72.93
	F-G	do	32.23	18.19	80.59		D-E	do	34.95	16.72	72.59
G''	C	do	36.75	12.16	80.63	K	F-G	do	29.71	18.11	72.23
	D-E	do	33.39	15.02	74.23		C	Nov. 3	37.35	12.61	77.98
	F-G	do	34.88	14.74	75.97		D-E	do	33.85	15.87	78.00
S	C	do	32.64	12.02	68.60	N	F-G	do	29.85	17.88	76.40
	D-E	do	29.70	16.70	79.77		C	do	37.37	9.23	77.83
	F-G	do	27.73	16.86	80.25		D-E	do	34.47	12.79	78.27
K	B	Nov. 7				L	F-G	do	29.17	15.12	78.39
	C	do	32.84				A	do	48.55	5.64	76.43
	D-E	do	30.54	12.91	77.03		B	do	42.60	6.79	76.04
G'	F-G	do	30.15	14.13	83.35	1926	C	do	38.52	9.94	75.17
	C	do	34.52	12.65	81.59		D-E	do	33.45	12.11	76.63
	D-E	do	30.15	13.75	71.96		F-G	do	29.88	16.81	75.16
G''	F-G	do	20.93	17.34	77.34	N	C	Sept. 24	37.77	15.33	76.82
	C	do	37.91	9.00	81.31		D	do	33.37	18.71	74.20
	D-E	do	25.22	12.98	75.55		E	Sept. 29	36.86	18.07	77.00
K	F-G	do	21.91	13.93	73.09	N	F	do	32.27	22.06	73.38
	C	do	28.12	9.85	75.94		C	Sept. 24	31.75	20.09	75.47
	D-E	do	27.42	13.88	80.99		D	Oct. 15	37.71	12.13	76.35
S	F-G	do	20.87	15.35	77.43	N	E	do	31.98	12.69	75.74
	C	Nov. 14	30.29	8.92	75.72		F	do	30.44	16.12	76.47
	D-E	do	30.87	12.57	80.56		C	Nov. 20	30.62	8.35	74.75
1925	F-G	do	28.55	13.74	79.46	N	D	do	28.90	11.11	77.00
	C	Oct. 2	37.28	11.79	75.63		E	do	27.06	12.85	79.27
	D-E	do	31.01	14.72	72.96						
S	F-G	do	29.74	17.17	75.92						
	H	do	23.98	15.51	74.98						

¹ Sugar percentages calculated on moisture-free basis in all cases. ² According to Table 1 and Plate 1.

A study of Table 2 shows that the moisture content declines from over 40 per cent in the immature fruit to 30 per cent and less in fruit sufficiently far advanced to make it suitable for processing, while that which is partially dried and wrinkled on the tree contains less than 20 per cent. There is some indication that fruit picked in September contains more moisture than comparable fruit picked a month or more later, although the higher atmospheric humidity during the late harvest season might be expected to have a contrary effect. This tendency is especially indicated by the data on fruit in stage D-E. The less mature fruit (stages B and C), as well as that which is riper (stage F-G), is less uniform within the lot, and the data concerning them do not show any pronounced trend. That rainfall will increase the moisture content of the fruit is plainly indicated. In 1925 fruit that was picked on October 20 and November 3, after a rainfall of several inches on October 4, contained considerably more moisture than comparable fruit picked on October 2. The amount of irrigation water used and the frequency with which it is applied no doubt have a decided effect on the moisture of the fruit, which probably accounts, to some extent at least, for the differences in the moisture content of the dates of comparable stages of maturity obtained from different gardens.

The Deglet Noor date acquires its maximum sugar content relatively early (13). Immature fruit, designated in Table 1 as full rose, generally contains as high a percentage of sugar, calculated on the dry weight exclusive of the seed, as more mature fruit, but the actual weight of sugar in the individual dates naturally increases as the percentage of dry matter increases with progressive ripening. The sugar in the early stages is mainly cane sugar, relatively small percentages of reducing sugars being present; but as ripening proceeds the inversion of the cane sugar continues slowly but steadily. The rate of this inversion on the tree is apparently accelerated by hot weather, because it is observed that fruit picked in November contained a larger proportion of reducing sugar than that of comparable maturity which ripened earlier in the season when higher seasonal temperatures prevailed. On the whole, the inversion of cane sugar proceeds quite definitely in accordance with distinct physical changes in the fruit, and it is possible, therefore, if desired in packing-house procedure, to sort the fruit on the basis of its physical characteristics and thus separate that which contains a relatively high proportion of reducing sugar from fruit less advanced in this respect.

From the data given in Table 2 and from general observations made during three seasons it is evident that fruit from different gardens and picked at different periods during the harvest varies considerably in character. This fact makes it important that date-packing houses be provided with the facilities necessary for handling separately the various lots of fruit received so that the maximum amount of fruit of good quality may be produced.

EFFECT OF PROCESSING CONDITIONS

The pronounced effect of the temperature in the processing room on the physical changes in the Deglet Noor date, and especially on the rate of inversion of cane sugar, has long been known. About 25

years ago Forbes (5, p. 472) reported on the work of Slade, who discovered that dates could be roughly classified into cane-sugar and invert-sugar dates and that the Deglet Noor is a typical cane-sugar date. Following the death of Slade in 1905 Vinson (12) continued the work on artificial processing, but later laid aside the heat-treatment method in favor of treatment with chemicals. Freeman (7), investigating the possibilities of processing dates by incubation, used temperatures as high as 120° F., but found that this treatment resulted in the inversion of most of the cane sugar. In his opinion the use of lower temperatures to conserve the cane sugar required too much time and thus increased the liability of the fruit to become sour. In 1912 Swingle (10) first called attention to the changes, due to the slow action of moderate heat, that take place in Deglet Noor dates in the packing cases while in transit from the Sahara, and pointed out the commercial possibilities of using similar conditions in the artificial maturation of this variety in the United States. Drummond (3), in 1924, reported the results of low-temperature maturation, which indicated that partially ripe Deglet Noor dates may be developed into good marketable fruit by subjecting them to a temperature not exceeding 90° for about five days. The benefits of such treatment are now readily evident, and much of the procedure in Deglet Noor packing houses is based thereon. High-temperature processing of Deglet Noor dates is now used almost exclusively for salvaging fruit that contains too much moisture to permit its being handled by any other method. However, Swingle (11) has pointed out that such dates may perhaps be dried sufficiently at a temperature not in excess of 90° by means of air dried by refrigeration, thus reducing the necessity of using the higher temperatures for such fruit.

The results obtained are largely in accord with those reported by previous investigators. The temperatures to which the fruit is subjected and the time of such exposure determine the final condition of the fruit, and both of these factors must be properly controlled in accordance with the requirements of the fruit under treatment in order to derive the maximum benefit from artificial processing.

The progressive maturation of the dates under such conditions may be observed by the following changes: (1) Darkening of the skin and flesh; (2) elimination of the rag and deposition of the tannin; and (3) increase in the amount of reducing sugars present. A temperature of 110° F. or even 90° for a sufficient length of time to completely eliminate the rag darkens the fruit too much and causes the inversion of enough of the cane sugar to produce a sirupy condition. If the fruit is not too far advanced, short exposure at 90° or longer periods at 60° to 75° permits it to assume the proper color and eliminates most of the rag before too much of the cane sugar is inverted. Apparently the ratio of total sugars to dry matter is not affected by the processing. Such differences as have been observed are not greater than normal variations in the fruit and can not be ascribed to any particular condition of treatment. The chief consideration, therefore, is to maintain the conditions of processing within such limits that the fruit will be brought as nearly as possible to its best condition in all respects so that if necessary it may be stored for a considerable time at a sufficiently low temperature to reduce further

inversion of cane sugar to a minimum and without loss of the desired color and texture. The normal progressive changes in the fruit when induced and stimulated by proper processing conditions can not be entirely checked after it has acquired its best quality, but by prompt removal from the processing rooms to proper conditions of temperature changes that tend to deteriorate the fruit may be considerably retarded. This is more fully described in the section on the storage of dates.

TABLE 3.—Effect of processing temperature on the moisture and sugar content¹ of Deglet Noor dates

Season and stage of maturity ²	Determinations before treatment			Temperature	Time	Determinations after initial treatment			Temperature used	Additional time	Determinations after additional treatment		
	Moisture	Sugars				Moisture	Sugars				Moisture	Sugars	
		Reducing	Total				Reducing	Total				Reducing	Total
November, 1925	P. ct.	P. ct.	P. ct.	° F.	Days	P. ct.	P. ct.	P. ct.	° F.	Days	P. ct.	P. ct.	P. ct.
A-----	48.55	5.64	76.43	<div><div>60-75</div><div>95</div><div>110</div></div>	<div><div>9</div><div>9</div><div>7</div></div>	<div><div>42.99</div><div>27.85</div><div>31.09</div></div>	<div><div>8.29</div><div>16.71</div><div>18.83</div></div>	<div><div>76.16</div><div>75.49</div><div>74.70</div></div>	<div><div>105</div></div>	<div><div>7</div></div>	<div><div>33.20</div></div>	<div><div>27.52</div></div>	<div><div>74.34</div></div>
B-----	42.60	6.79	76.04	<div><div>60-75</div><div>95</div><div>110</div></div>	<div><div>9</div><div>9</div><div>6</div></div>	<div><div>38.63</div><div>24.53</div><div>31.98</div></div>	<div><div>8.18</div><div>18.62</div><div>26.17</div></div>	<div><div>76.82</div><div>76.72</div><div>76.19</div></div>	<div><div>105</div></div>	<div><div>4</div></div>	<div><div>32.27</div></div>	<div><div>18.85</div></div>	<div><div>75.36</div></div>
C-----	38.52	9.94	75.17	<div><div>60-75</div><div>95</div><div>110</div></div>	<div><div>7</div><div>6</div><div>6</div></div>	<div><div>37.63</div><div>30.85</div><div>18.32</div></div>	<div><div>11.87</div><div>26.25</div><div>34.50</div></div>	<div><div>75.64</div><div>76.98</div><div>78.73</div></div>	<div><div>95</div></div>	<div><div>2</div></div>	<div><div>25.64</div></div>	<div><div>19.73</div></div>	<div><div>75.44</div></div>
D-E-----	33.45	12.11	76.63	<div><div>95</div><div>110</div></div>	<div><div>2</div><div>2</div></div>	<div><div>33.32</div><div>30.43</div></div>	<div><div>18.59</div><div>19.62</div></div>	<div><div>75.71</div><div>76.03</div></div>	<div><div>95</div><div>110</div></div>	<div><div>2</div><div>2</div></div>	<div><div>23.24</div><div>17.22</div></div>	<div><div>21.19</div><div>30.84</div></div>	<div><div>75.63</div><div>75.20</div></div>
F-----	29.88	16.81	75.16	<div><div>95</div><div>110</div></div>	<div><div>2</div><div>2</div></div>	<div><div>28.22</div><div>29.72</div></div>	<div><div>20.66</div><div>21.54</div></div>	<div><div>75.72</div><div>76.28</div></div>	<div><div>95</div><div>110</div></div>	<div><div>2</div></div>	<div><div>18.34</div><div>16.13</div></div>	<div><div>24.65</div><div>33.04</div></div>	<div><div>75.05</div><div>74.86</div></div>
October, 1926													
D-----	31.98	12.69	75.74	95	2	28.85	16.44	76.79	60-75	12	23.75	17.88	77.30
D-----	31.98	12.69	75.74						60-75	14	27.64	16.83	77.69
E-----	30.44	16.12	76.47						60.75	14	24.20	19.27	76.32

¹ Sugar percentages calculated on moisture-free basis in all cases. ² According to Table 1 and Plate 1.

The effect of processing conditions on fruit of various stages of maturity is shown in Table 3. Immature fruit designated "full rose" and "half rose" has not reached a sufficiently advanced stage on the tree to permit successful processing. A temperature of 90° to 95° F. will cause the skin to change to a cinnamon or hazel color and the flesh to soften, but the time required to bring it to the desired physical condition, readily acquired by riper fruit, is too long to be practicable. In more mature "turning" fruit the rag can be softened and greatly reduced at 90° to 95° before there is too much inversion of cane sugar and before the skin darkens to an objectionable degree. Soft ripe fruit comes from the tree with a considerable proportion of reducing sugars. For that reason if it is processed for more than a brief period it becomes sirupy on account of the further inversion of cane sugar, and the skin turns dark. Such fruit dries and conditions well at 70° to 80° and should not be subjected to higher temperatures. Soft wrinkled and semidry fruits vary greatly in the amount of rag and reducing sugars present, depending on the stage of maturity at which they began to shrivel on the tree. Three general classes of such fruit may be recognized:

(1) Dark fruit, with a high ratio of reducing sugar, which causes it to deteriorate rapidly in appearance and flavor when processed; (2) hazel-colored fruit, which is ripened and conditioned on the tree and which deteriorates when processed at 90° or above; (3) light-colored fruit, with rose or light brownish purple stem end rings and considerable rag. The last-mentioned type has dried prematurely but is of good flavor and may be marketed as a dry date. It is too dry, however, to be improved by the usual processing treatment used for turning fruit.

EFFECT OF SLOW PROCESSING ON GENERAL CONDITIONING OF FRUIT

During three seasons Deglet Noor dates from different localities and of several stages of maturity were processed at 90° to 95° F. over a period of days, and the effect of the processing was noted by determining the moisture and reducing-sugar content at intervals while the processing continued. The relationship of the moisture content to the condition of the fruit was given special attention, in seeking a practical way to so control the conditions of processing that the conditioning of the fruit with respect to moisture content could proceed as far as possible coincident with the other changes that are induced in the fruit during such treatment. Table 4 shows the extent to which moisture may be reduced when the relative humidity of the room is low. General observations have indicated that if a relative humidity of 75 to 85 per cent is maintained in the processing room by means of humidifiers, fruit which is in good condition to be successfully processed but which contains considerably more moisture than is permissible for packing or storing loses only a relatively small proportion of such excess moisture. On the other hand, a relative humidity as low as 25 or 35 per cent causes an appreciable reduction in the moisture content but at the same time does not interfere with the normal processing of the fruit. Although there is some indication that if the humidity is too low the desired changes in the color of the skin and texture of the flesh will be retarded, it is evident that a temperature of 90° to 95° with a relative humidity of 25 to 35 per cent will effect not only normal processing but a beneficial conditioning in fruit that is suitable for such treatment. If a procedure based on this fact is adopted it will to some extent remove the necessity for subsequently holding the fruit in trays and will thus simplify packing-house operations.

TABLE 4.—*Moisture and reducing-sugar content*¹ of Deglet Noor dates from different localities processed at 95° F.

Stage of maturity ² and locality	Time of picking	Relative humidity in room	Determinations											
			When picked		After 1 day		After 2 days		After 3 days		After 4 days		After 7 days	
			Mois-ture	Reduc-ing sugar	Mois-ture	Reduc-ing sugar	Mois-ture	Reduc-ing sugar	Mois-ture	Reduc-ing sugar	Mois-ture	Reduc-ing sugar	Mois-ture	Reduc-ing sugar
			<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
C	SK ³ -----	Oct. 6, 1924	High	37.75	13.27									
	N-----	Oct. 2, 1925	Low	36.22	14.25			40.21	23.19	25.92	27.54			
	L-----	do	do	37.26	15.48					26.83	26.42			
	K-----	do	do	35.48	12.34					26.55	23.32			
	S-----	do	do	37.28	11.79					25.72	19.05			
	N-----	Oct. 20, 1925	do	38.44	11.66								25.45	25.63
	K-----	do	do	38.49	11.93								26.45	25.75
	S-----	do	do	39.20	11.13								24.27	22.17
	N-----	Nov. 3, 1925	do	37.36	9.23							31.55	17.47	
	K-----	do	do	37.35	12.61							30.63	22.93	
	N-----	Sept. 24, 1926	do	37.77	15.33			31.87	23.49					
	N-----	Oct. 14, 1926	do	37.71	12.13			30.59	15.67					
D	N-----	Sept. 24, 1925	do	33.37	18.71			28.50	22.34					
	N-----	Sept. 29, 1926	do	36.86	18.07	31.47	22.48							
	N-----	Nov. 20, 1926	do	29.75	9.73			22.25	12.62					
	SK ³ -----	Oct. 6, 1924	High	37.26	17.00			37.13	25.59					
	S-----	Oct. 20, 1924	Low	34.35	16.42	28.35	19.56	24.62	21.62					
	K-----	do	do	37.14	18.93	32.39	20.60	28.94	23.28					
	S-----	Nov. 7, 1924	do	30.54	12.91			30.08	15.06					
	K-----	do	do	30.15	13.75			29.76	20.04					
	K-----	Nov. 14, 1924	do	30.87	12.57			32.22	18.50					
	N-----	Oct. 2, 1925	do	31.09	17.52			23.07	25.27					
	L-----	do	do	31.65	19.72			26.97	28.22					
	K-----	do	do	29.46	17.11			24.67	20.15					
D-E	S-----	do	do	32.01	14.72			25.05	15.94					
	N-----	Oct. 20, 1925	do	34.95	16.72			25.86	20.88					
	K-----	do	do	33.30	18.33			25.84	22.73					
	S-----	do	do	34.35	12.82			26.60	19.56					
	N-----	Nov. 3, 1925	do	32.47	12.79			24.61	16.26					
	K-----	do	do	33.85	15.87			26.16	21.17					

F-G-----	K-----	Oct. 20, 1924	High-----	32.23	18.19	-----	-----	21.91	21.27	-----	-----	-----	-----	-----
	K-----	Nov. 7, 1924	--do-----	20.93	17.34	-----	-----	16.46	19.33	-----	-----	-----	-----	-----
	K-----	Nov. 14, 1924	--do-----	28.55	13.74	-----	-----	25.21	17.32	-----	-----	-----	-----	-----
	N-----	Oct. 2, 1925	Low-----	25.77	19.68	-----	-----	17.95	22.56	-----	-----	-----	-----	-----
	L-----	do-----	--do-----	29.08	21.25	-----	-----	23.96	28.68	-----	-----	-----	-----	-----
	K-----	do-----	--do-----	24.96	18.50	-----	-----	24.39	21.89	-----	-----	-----	-----	-----
	S-----	do-----	--do-----	29.74	17.17	-----	-----	22.57	19.07	-----	-----	-----	-----	-----
	N-----	Oct. 20, 1925	--do-----	29.71	18.11	24.96	21.19	-----	-----	-----	-----	-----	-----	-----
	K-----	do-----	--do-----	29.51	18.88	24.48	20.59	-----	-----	-----	-----	-----	-----	-----
	S-----	do-----	--do-----	30.74	13.68	25.71	19.33	-----	-----	-----	-----	-----	-----	-----
	N-----	Nov. 3, 1925	--do-----	29.17	15.12	-----	-----	26.05	16.13	-----	-----	-----	-----	-----
	K-----	do-----	--do-----	29.85	17.88	-----	-----	25.17	19.65	-----	-----	-----	-----	-----
	N-----	Sept. 24, 1926	--do-----	31.76	20.09	-----	-----	27.97	24.71	-----	-----	-----	-----	-----

¹ Sugar percentages calculated on moisture-free basis in all cases.

² According to Table 1 and Plate 1.

³ Mixture of fruit from gardens S and K.

Turning and soft ripe dates generally contain more than 30 per cent of moisture when picked, and although this percentage is reduced by processing in relatively dry air, most of the fruit will require more drying after the desired color and texture have been obtained in the processing room. In order to insure good keeping qualities it appears that the fruit should contain not more than 25 per cent of moisture. This makes a reasonably soft, attractive date that will not readily mold or turn sour. It follows, therefore, that the longer the fruit is to be held the more important it is that the moisture should be reduced to the percentage mentioned. Several methods are used for drying dates by circulating air. In order to minimize inversion, the drying should be done at a temperature not in excess of 70° F. In the experiments here recorded shallow trays with wire bottoms allowing a free circulation of air were used with good results. By this method the moisture of the dates was reduced to the extent desired in about a week without any material increase in the proportion of reducing sugars.

Table 4 shows that under the conditions described the rate of inversion of cane sugar is fairly constant in the fruit from the several gardens and that the amount of reducing sugar present when the fruit reaches a marketable condition depends primarily on the extent to which inversion has progressed when the fruit is picked. Consequently, fruit that goes into the processing room with a relatively high percentage of reducing sugar is very likely to become sirupy by the time it has reached a satisfactory condition of color and texture. It has been mentioned elsewhere that fruit picked early in the harvest season contains proportionately more reducing sugar than fruit of comparable appearance picked later. It follows, therefore, that late-season fruit may be brought to the desired color and texture without too much inversion of cane sugar, but that early-season fruit of approximately the same stage of maturity presents more of a problem in this respect.

Fruit of comparable appearance picked at the same time from the several gardens differed somewhat in the amount of moisture and reducing sugar present, but on the whole comparable lots of such fruit may be processed under the same conditions with reasonably uniform results. A packing house receiving fruit from different gardens must be equipped to handle many lots of fruit according to their condition. There is evidence to show that three sets of conditions with respect to processing and conditioning will adequately handle the several lots of fruit usually received from the gardens and produce a maximum proportion of good, marketable fruit. There should be available: (1) Rooms at 95° F. for fairly rapid processing; (2) rooms at 80° for slow processing and conditioning; and (3) rooms at 60°, preferably with circulating air, for conditioning with a minimum inversion of cane sugar.

Daily sorting of the fruit that has progressed far enough in the processing rooms, especially in those rooms where the higher temperatures are maintained, will assure the production of the largest proportion of choice fruit. This is practicable only on a small scale. In no single lot of dates, no matter how carefully sorted on the basis of physical character, will all the individual fruits process at the same rate or in the same way. Unless sorted at intervals, some of them will stay in the processing room too long. The best prac-

tical means to achieve the desired result is to sort the fruit carefully before it goes into the processing rooms. Such grading is best accomplished by separating the fruit into (1) dark-colored fruit, (2) normal-colored fruit without regard to softness or wrinkles, and (3) culls (immature, deformed, and dry fruit). The dark fruit usually requires no treatment other than conditioning for moisture. It contains considerable reducing sugar, and if the rag has not already been largely eliminated processing at 95° F. or above in order to accomplish this will further darken the skin and may cause sirup to form in the soft flesh. The normal-colored fruit represents a rather wide range of maturity. It may all be satisfactorily processed, but the time required will vary according to its softness and the firmness of the shoulder and center. It should therefore be re-sorted on that basis into several grades and each grade handled according to its needs. The culls are too lacking in uniformity to permit the recommendation of any definite procedure. Briefly stated, fairly rapid processing at a moderately low temperature (90° to 95°) apparently produces the best quality of fruit. Such treatment is preferable to the use of a somewhat higher temperature for a shorter period, because it is more likely to bring about elimination of the rag before the color becomes too dark and the excessive inversion of cane sugar causes a sirupy condition. The several changes mentioned do not always progress uniformly with respect to one another. At higher temperatures the change in color and inversion of cane sugar proceed at times much more rapidly than the elimination of the rag. Semimature fruit when subjected to such temperatures frequently becomes sirupy at the tip and immediately under the skin some time before the rag is eliminated.

EXPERIMENTS ON STORAGE

The possibility of storing dates at 34° to 36° F. was suggested as early as 1917, when Forbes (6) reported that a number of experiments were undertaken at the Arizona Agricultural Experiment Station. These experiments, however, did not include the Deglet Noor variety. In recent years the use of cold storage in connection with this variety has received serious consideration. According to Swingle (9), who reported a number of preliminary tests made in 1924 and 1925, the method has practical possibilities.

General observation of the physical condition of commercially packed fruit that had been stored for three or four months at 32° F. in a preliminary test by the writers indicated that the fruit does not come out of cold storage in a uniform condition. Some of it retained the hazel color and characteristic flavor it possessed when packed and was neither sirupy nor too dry. The remainder was chestnut in color, distinctly sirupy, soft in texture, and was entirely lacking in the Deglet Noor flavor. It also contained slightly more moisture than the fruit of better quality. The total sugar content of the two classes of fruit was about the same, but in the fruit of poor quality the inversion of cane sugar had progressed further, as was indicated by the percentage of reducing sugars present. This amounted to 30 to 33 per cent in the poorer fruit, whereas in the better fruit it was only 20 to 25 per cent. In the fruit of good quality some of the rag

still remained, but in that of poor quality it had been entirely eliminated.

In view of these observations, further storage tests were undertaken to ascertain the relationship of the condition of the fruit when placed in storage to its keeping qualities under various conditions of storage. Most of these tests were conducted with processed fruit stored in bulk and in paper boxes of 1-pound capacity with waxed-paper lining. Such fruit was separated according to its physical condition into fairly distinct grades⁵ designated as A, B, C, and D. The characteristics of these grades are shown in Plate 2 and are described in Table 5. Some unprocessed fruit which had matured considerably on the tree was also used but was stored in bulk only. This fruit was separated into two lots corresponding in characteristics to stages D and E shown in Plate 1 and described in Table 1. All the fruit was placed in storage under the following temperature conditions: 32° F., representing commercial cold storage; 50° to 60°, representing cellar storage; and 60° to 70°, representing storage in the laboratory. Table 6 shows the moisture content and the reducing and total sugar content of the fruit when placed in storage, also during and after storage. Table 7 shows the physical condition during the same observation period.

TABLE 5.—*Physical characteristics of the several grades of processed Deglet Noor dates used in storage tests*

Grade	Color		Texture	Proportion of rag
	Skin	Stem end		
A.....	Cinnamon.....	Light brownish purple.	Pliable.....	About three-fourths at shoulder.
B.....	Hazel with cinnamon shoulder.	do.....	do.....	About one-half at shoulder. ^c
C.....	Hazel.....	Hazel.....	do.....	About one-fourth at shoulder. ^c
D.....	Russet.....	do.....	Slightly soft, with tendency to become sirupy in seed cavity.	None.

^c Late-season fruit graded as B and C according to external appearance is likely to have a somewhat higher proportion of rag than here indicated.

⁵ The designation of the several grades of processed fruit by letters is used here for convenience and should not be understood to indicate that standard commercial grades of the fruit designated by such terms have been established by the Government.



Four grades of processed Deglet Noor dates used in storage tests. (Natural size.)
For a description of these grades of fruit see Table 5

TABLE 6.—*Effect of various conditions of storage on the moisture and sugar content*¹ of processed and nonprocessed Deglet Noor dates

Grade and stage of maturity ²	Time of picking	Treatment	Package	Determinations before storage			Storage temperature	Determinations after storage for—												
								2 to 3 months			5 to 6 months			8 to 9 months			10 months			
				Mois- ture	Re- duc- ing sugar	Total sugar		Mois- ture	Re- duc- ing sugar	Total sugar	Mois- ture	Re- duc- ing sugar	Total sugar	Mois- ture	Re- duc- ing sugar	Total sugar	Mois- ture	Re- duc- ing sugar	Total sugar	
Grades A and B	1926 Sept. 24	Processed	1-pound box	P. ct.	P. ct.	P. ct.	° F.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
				22. 21	22. 61	77. 95	60-70	15. 07	28. 15	75. 05	22. 97	26. 85	77. 59	23. 14	20. 91	78. 63	25. 91	27. 74	78. 13	
			Bulk				50-60	23. 01	28. 83	77. 59										
							32	20. 71	21. 75	75. 85										
							60-70	14. 10	26. 54	74. 78										
				27. 27	20. 30	73. 78	50-60	22. 55	29. 89	76. 73										
Stage D	do	Nonprocessed	do				32	24. 94	22. 31	75. 55	26. 42	22. 40	75. 27	29. 91						
							60-70	14. 28	29. 84	75. 12										
			do	29. 51	18. 07	77. 00	50-60	25. 17	30. 95	77. 21										
							32	27. 63	20. 92	75. 86	29. 73	25. 67	77. 94	31. 21	23. 15	78. 14				
							60-70	19. 61	36. 29	74. 74										
							50-60	25. 37	33. 93	77. 12										
Grades C and D	do	Processed	1-pound box	24. 05	28. 70	75. 01	32	25. 51	32. 39	74. 66	26. 63	36. 46	77. 84	26. 24	34. 71	78. 17				
							60-70	15. 56	31. 97	75. 74										
			Bulk				50-60	22. 36	26. 09	76. 36										
				27. 42	24. 60	75. 88	32	24. 19	25. 99	74. 49	28. 04	32. 11	76. 99	28. 69	33. 53	78. 34				
							60-70	13. 30	36. 63	74. 97										
							50-60	22. 22	31. 37	76. 94										
Stage E	do	Nonprocessed	do	28. 08	22. 06	73. 38	32	26. 99	23. 99	75. 97	29. 18	28. 92	78. 49	31. 18	38. 42	78. 40				
							60-70	14. 40	19. 57	75. 07	17. 77	23. 44	76. 60							
			do	23. 03	17. 58	77. 06	50-60	22. 21	20. 00	76. 27	27. 08	22. 97	77. 94							
							32	23. 10	17. 46	74. 96	26. 81	19. 96	78. 03							
							60-70	12. 50	23. 64	76. 51										
							50-60	23. 60	20. 48	75. 66										
Grades A and B	Oct. 14	Processed	do				32	25. 55	16. 94	76. 07	24. 91	16. 61	75. 95	23. 52	23. 00	76. 77				
							60-70	17. 51	23. 57	75. 91										
			do	24. 46	18. 17	77. 54	50-60	24. 10	21. 25	74. 35										
							32	24. 71	19. 40	77. 12	28. 17	20. 09	78. 97							
							60-70	15. 04	23. 12	75. 07										
							50-60	26. 69	22. 18	76. 97										
Stage D	do	Nonprocessed	do	24. 20	19. 27	76. 32	32	24. 24	20. 34	76. 98	24. 31	19. 75	77. 22	24. 06	27. 14	78. 21				
							60-70	15. 33	16. 70	79. 21										
			do				50-60	23. 22	16. 51	77. 04	23. 90	20. 08	77. 94							
							32	23. 50	13. 09	77. 16	22. 90	14. 71	77. 91	23. 02	17. 05	76. 88	22. 09	16. 45	76. 19	
							60-70	17. 01	22. 28	78. 26										
							50-60	25. 31	20. 83	77. 37	24. 75	25. 26	79. 03							
Grades C and D	do	do	do	22. 94	13. 08	74. 09	32	25. 00	16. 34	76. 84	24. 80	15. 36	77. 69	23. 98	21. 73	78. 07	23. 84	20. 33	76. 85	
			do																	

¹ Sugar percentages calculated on moisture-free basis in all cases.

² Grade refers to A, B, C, D of Plate 2; stages of maturity refer to A, B, C, D, E, F, G, H of Plate 1.

Table 6 shows that storage temperatures have a direct influence on the inversion of cane sugar. At 32° F. the inversion was very slight, but at the higher temperatures, especially those prevailing in laboratory storage, the inversion was sufficient in most of the several lots of fruit to cause a sirupy condition. Fruit that entered storage with a low percentage of reducing sugar as a rule came out with a lower reducing-sugar content than that in which greater inversion occurred prior to storage. In other words, the several conditions of storage used caused the inversion of cane sugar to proceed at a rather definite rate, depending on the temperature. Fruit picked late in the season went into storage with less reducing sugar and came out with less than fruit picked earlier in the season.

Table 7 shows the effect of storage temperature on the color, texture, and flavor of the fruit. The color darkens gradually, somewhat in advance of sirup formation, and the characteristic flavor appears to linger after the sirup starts to form. Experience has shown that the fruit should be marketed and consumed before the characteristics of the fresh dates have disappeared to a marked degree. Fruit with a general chestnut color, or darker than russet (pl. 2, D), with sirupy flesh and lacking characteristic flavor must be considered as past the condition desirable for marketing. Deterioration of the physical characteristics is shown to be consistently associated with the diminishing of the rag and the increase in reducing-sugar content. This deterioration is most rapid when the storage temperature is high. When placed in storage both the partly matured, unprocessed fruit and the fruit not fully processed had considerably more rag at the shoulder than the naturally matured or fully processed fruit, and this difference was maintained throughout the storage period. The first-mentioned fruit did not deteriorate in storage and upon removal had still about half the rag at the shoulder. It was observed that at all three temperatures the fruit that had a light brownish purple ring at the stem end when placed in storage retained its fresh color, nonsirupy texture, and characteristic flavor longer than the more mature or fully processed fruit from which this color ring had disappeared. The color ring fades in storage but does not completely vanish for many months. *It is evident, therefore, that the stem-end color ring is of value as an indicator of relative maturity in selecting fruit for long storage.*

Humidity conditions in the storage rooms appear to affect only the moisture content of the fruit. The extent to which moderately dry dates absorb moisture was shown by placing fruit containing only 15 per cent moisture in net bags in a bulk package of dates having a moisture content of 24 per cent. After one month in cellar storage at 50° to 60° F. the dry dates had become distinctly pliable, because of the absorption of 5 per cent of moisture. Under cellar storage with 85 per cent humidity the fruit does not change much in moisture content, but if the humidity is somewhat higher the fruit will absorb moisture in the course of a few months and mold. Fruit stored at 32° with high humidity absorbs some moisture but develops no mold in 8 to 10 months. Since the air in commercial cold-storage rooms usually has a relative humidity of about 85 per cent, it would appear that fruit in such storage would suffer practically no loss of moisture.

TABLE 7.—Effect of various conditions of storage on the physical characteristics of processed and nonprocessed Deglet Noor dates

Grade and stage of maturity ¹	Time of picking	Treatment	Package	Determinations			Storage temperature	Determinations after storage for—																
				Moisture	Reducing sugar ²	Total sugar		2 to 3 months					5 to 6 months					8 to 9 months						
								Color of skin	Color ring at stem end	Texture and general condition	Rag at shoulder	Characteristic flavor	Color of skin	Color ring at stem end	Texture and general condition	Rag at shoulder	Characteristic flavor	Color of skin	Color ring at stem end	Texture and general condition	Rag at shoulder	Characteristic flavor		
Grades A and B.....	1926 Sept. 24	Processed.....	{1-pound box.....	Per cent	Per cent	Per cent	° F.	60-70 Chestnut.....	Present ³	Leathery.....	1/4-1/2	Slight.....												
				22.21	22.61	77.95	50-60 Russet.....	do.....	Pliable.....	1/4-1/2	Full.....	Russet.....	Present ³	Sirupy.....	1/4-1/2	Slight.....	Hazel.....	Present ³	Pliable.....	1/4-1/2	Full.....			
			{Bulk.....	27.27	20.36	73.78	60-70 Russet.....	do.....	Leathery.....	1/4-1/2	Slight.....	Chestnut.....	do.....	Leathery.....										
				29.51	18.07	77.00	50-60 do.....	Absent.....	Sirupy.....	0-1/4	do.....	do.....	Absent.....	Moldy.....	1/4-1/2	Full.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	None.....			
Stage D.....	do.....	Nonprocessed.....	{do.....	29.51	18.07	77.00	60-70 Chestnut.....	Absent.....	Leathery.....	0-1/4	None.....	Chestnut.....	do.....	Leathery.....										
				29.51	18.07	77.00	50-60 do.....	do.....	Sirupy.....	0-1/4	do.....	do.....	Moldy.....											
			{1-pound box.....	24.05	28.70	75.01	60-70 Chestnut.....	Present.....	Pliable.....	1/2-3/4	Full.....	Russet.....	do.....	Pliable.....	0-1/4	Full.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	None.....			
				27.42	24.60	75.88	50-60 Russet.....	do.....	Sirupy.....	0-1/4	do.....	Chestnut.....	Absent.....	Moldy.....	0-1/4	Slight.....	Russet.....	Absent.....	Sirupy.....	0-1/4	None.....			
Grades C and D.....	do.....	Processed.....	{Bulk.....	27.42	24.60	75.88	60-70 Chestnut.....	do.....	Leathery.....	0-1/4	do.....	do.....	Chestnut.....	do.....	Leathery.....									
				27.42	24.60	75.88	50-60 do.....	do.....	Sirupy.....	0-1/4	do.....	do.....	Moldy.....											
			{do.....	28.08	22.06	73.38	60-70 Chestnut.....	do.....	Leathery.....	0-1/4	None.....	Russet.....	do.....	Sirupy.....	0-1/4	Slight.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	None.....			
				28.08	22.06	73.38	50-60 do.....	do.....	Sirupy.....	0-1/4	do.....	do.....	Moldy.....	0-1/4	Full.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	None.....				
Grades A and B.....	Oct. 14	Processed.....	{do.....	23.03	17.58	77.06	60-70 Hazel.....	Present.....	Leathery.....	1/2-3/4	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	
				23.03	17.58	77.06	50-60 do.....	do.....	Pliable.....	1/2-3/4	do.....	Hazel.....	do.....	Pliable.....	1/4-1/2	Full.....	do.....	do.....	Pliable.....	1/4-1/2	Full.....			
			{do.....	27.64	16.83	77.69	60-70 do.....	do.....	Leathery.....	1/2-3/4	Slight.....	Chestnut.....	Absent.....	Leathery.....										
				27.64	16.83	77.69	50-60 do.....	do.....	Pliable.....	1/2-3/4	Full.....	Hazel.....	Present.....	Pliable.....	1/2	Full.....	Russet.....	Present.....	Sirupy.....	1/4-1/2	Slight.....			
Grades C and D.....	do.....	Processed.....	{do.....	24.46	18.17	77.54	60-70 Chestnut.....	Absent.....	Leathery.....	1/2-1/2	Slight.....	Chestnut.....	Absent.....	Leathery.....										
				24.46	18.17	77.54	50-60 do.....	do.....	Sirupy.....	0-1/4	None.....	do.....	do.....	Moldy.....										
			{do.....	24.20	19.27	76.32	60-70 Russet.....	do.....	Leathery.....	0-1/4	Slight.....	Russet.....	do.....	Sirupy.....	0-1/4	Slight.....	do.....	do.....	Sirupy.....	0-1/4	Slight.....			
				24.20	19.27	76.32	50-60 Chestnut.....	do.....	Leathery.....	0-1/4	do.....	Chestnut.....	do.....	Leathery.....										
Stage E.....	do.....	Nonprocessed.....	{do.....	24.20	19.27	76.32	60-70 Russet.....	do.....	Pliable.....	0-1/4	do.....	do.....	Hazel.....	do.....	Pliable.....	1/4-1/2	Full.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	Slight.....		
				24.20	19.27	76.32	50-60 do.....	do.....	Leathery.....	1/2-3/4	Full.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	Slight.....	do.....	do.....	Sirupy.....	0-1/4	Slight.....			
			{1-pound box.....	21.56	12.16	77.29	60-70 Russet.....	Present.....	Pliable.....	1/4-1/2	do.....	Chestnut.....	Absent.....	Sirupy.....	0-1/4	Slight.....	do.....	do.....	Sirupy.....	0-1/4	Slight.....			
				21.56	12.16	77.29	32 Hazel.....	do.....	do.....	1/4-1/2	do.....	Hazel.....	Present.....	Pliable.....	1/4-1/2	Full.....	Russet.....	Absent.....	Pliable.....	1/4	Full.....			
Grades C and D.....	do.....	do.....	{do.....	22.94	13.08	74.09	60-70 Chestnut.....	Absent.....	Leathery.....	1/4-1/2	do.....	do.....	Chestnut.....	Absent.....	Sirupy.....	0	Slight.....	do.....	do.....	Sirupy (slight)	1/4	Slight.....		
				22.94	13.08	74.09	50-60 do.....	do.....	Sirupy.....	1/4-1/2	do.....	Hazel.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	
			{do.....	22.94	13.08	74.09	60-70 do.....	do.....	Leathery.....	1/4-1/2	do.....	Chestnut.....	do.....	Leathery.....		do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....
				22.94	13.08	74.09	32 Hazel.....	do.....	Pliable.....	1/4-1/2	do.....	Hazel.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....	do.....

¹ Grade refers to A, B, C, D of Plate 2; stages of maturity refer to A, B, C, D, E, F, G, H of Plate 1.

² Sugar percentages calculated on moisture-free basis in all cases.

³ In all cases where this color ring was present in the stored fruit the color of the ring was pale in comparison with that present on the fruit before storage.

Packed fruit that was held in a fairly dry atmosphere in the laboratory dried excessively, in spite of the waxed-paper lining of the cartons and the additional outside wrapping of waxed paper. The pronounced influence of the type of package on the loss of moisture in dates has also been definitely shown by the experiments of Christie (2).

Swingle (9), in a report on some preliminary experiments on the storage of Deglet Noor dates at 33° F., showed that the effect of such temperature on the keeping quality of comparable grades of this fruit is the same, irrespective of the time when the fruit is picked. The writers found, however, that fruit, apparently mature, picked during the latter part of the season stored better than fruit of the same appearance picked earlier. This was probably because of the larger proportion of rag and the lower percentage of reducing sugar present in the late-season fruit. Attention has already been directed to the fact that in fruit maturing late in the season there is, on the whole, relatively less inversion of cane sugar than in otherwise comparable fruit that matures earlier.

In general, the effect of the several storage temperatures used on the Deglet Noor dates was definite and may be briefly summarized. At 60° to 70° F. fruit that is quite mature or fully processed (pl. 2, C and D) darkens and becomes sirupy. Less mature or partially processed fruit (pl. 2, A and B) retains a fair color and flavor for two or three months at room temperature, but the excessive loss of moisture under such conditions detracts from its appearance. The several types of fruit used store better at 50° to 60° than at the higher temperatures, but on the whole the best results are obtained with fruit that is only partially matured or processed. The indications are that none of the fruit can be successfully stored at this temperature longer than two or three months, because it becomes moldy. *Both types of fruit referred to store well at 32° for 5 or 6 months, and the more moderately processed grades (A and B) may be held successfully for 9 or 10 months.* The fruit comes out of such storage pliable rather than dry or leathery, and with good color and flavor. All the fruit is of marketable quality but not entirely uniform. The less mature fruit (A and B) retains more nearly the color and flavor of the fresh dates. The difference in color of the individual dates detracts from the appearance of the fruit when packed in boxes, but with reasonable care in packing this lack of uniformity can largely be avoided. The type of fruit that stores well always retains some rag at the shoulder. This does not detract from its quality, as the amount of rag is only a small portion of the flesh. In fact, there is some indication that the characteristic flavor of the Deglet Noor date is largely concentrated in the rag.

For bulk storage, especially of nonprocessed fruit, shallow open containers are probably necessary in order to insure some evaporation of moisture and to minimize the crushing of the fruit. Dates stored in bulk at low temperatures are likely to sweat when removed, because of the condensation of moisture in the air, but fruit stored in packages is protected from this condition if the packages are allowed to warm up before being opened. Since dates absorb odors, it is preferable to store them in packages rather than in bulk, especially if they are to be placed in rooms that contain other goods the odor of which might be absorbed.

EFFECT OF PASTEURIZATION AND FREEZING ON KEEPING QUALITY

The foregoing experiments show quite definitely that certain grades of Deglet Noor dates can be successfully stored at 32° F. for about six months. They also show that only fruit not fully matured on the tree or not fully processed can be held for a longer period without serious deterioration. There is much interest therefore in finding other ways to hold in storage successfully the large proportion of fruit that reaches an advanced stage of maturity on the tree before it is picked or that is fully processed in the packing house. Pasteurization to destroy the enzymes in the fruit with a view to checking the natural physiological changes that gradually cause its deterioration and to prevent souring has been in commercial use, particularly with other varieties than the Deglet Noor, as reported by Postlethwaite (8). The use of freezing temperatures to maintain the dates in a frozen condition until they are to be marketed has also been suggested. Swingle (9) states that in connection with some preliminary tests on the effect of cold storage on Deglet Noor dates made by the Deglet Noor Date Growers' Association in 1924 and 1925 it was found that a temperature of 10° F. caused the deposition of the tannin in unripe fruit, which fact was suggested as a possible explanation of the ripening effect of low temperatures on relatively green dates.

In this investigation some experiments were made on the effect of both pasteurizing and freezing, but the results were by no means conclusive, and further work is necessary to demonstrate whether these treatments have a more practical value for storage purposes than the less extreme temperatures. Dates containing about 13 per cent of reducing sugar were placed in fruit jars in a pasteurizing chamber for one and three-fourths hours. The temperature of the fruit when placed in the chamber was 65° F., and during the last half hour of the treatment the temperature was 137°. A slight caramel taste was developed, but the color and texture were not markedly affected. The fruit was then stored in the jars at 60° to 70°, and unheated fruit of the same lot was stored in similar containers for comparison. After eight months the heated fruit had 26.41 per cent of reducing sugar, whereas the unheated had 35 per cent. Similar fruit, unheated, but held in cold storage (32°) for the same period, contained 20 per cent. All three lots of fruit darkened during the period of the experiment, but retained to a slight extent the characteristic flavor. The heated fruit had a grainy texture, and the skin was leathery, owing to loss of moisture when it was heated. The unheated fruit held at 60° to 70° was moldy and sirupy, while the heated fruit held at that temperature and also the untreated fruit stored at 32° was not. The fruit in the lot last mentioned was the best of the three. It had a pliable texture and was on the whole attractive in appearance. Although more extensive experiments are necessary to demonstrate the effect of high-temperature treatment, the indications are that the quality of the fruit is better maintained by cold storage, but the beneficial action of heat in controlling mold and destroying invertase is recognized.

To observe the effect of freezing, experiments were made with processed fruit picked in October and November and graded into three lots corresponding to B, C, and D, as described in Table 5 and

illustrated in Plate 2. Average temperatures of 40°, 32°, 27°, and 10° F. were used, but not for all three lots. An inspection of the fruit was made after four months, and again one month after it had been removed to a room having a temperature of 60° to 70°. At 10° the fruit froze solid, but not at 27°. Table 8 shows the physical condition of the fruit at the two inspection periods and also the moisture and the reducing-sugar content. The amount of reducing sugar in the fruit after processing and before storing was not determined, and therefore definite information on the amount of inversion of cane sugar during the storage at low temperatures is not available from this test. The indications are that the amount was near the maximum percentage permissible in dates intended for storage. The proportion of rag present when the fruit is placed in storage is evidently important, since it appears that the characteristic flavor is most likely to be retained if about half the rag is still present at the shoulder, which is in accordance with results obtained in the other storage tests. At the temperature at which the fruit froze solid (10°) the flavor was preserved longer than at the higher temperatures, but this was true only in the case of fruit in which the rag was present to the extent mentioned and in which deteriorating changes had not yet definitely set in when it was placed in storage. This seems to indicate that in the more mature fruit such changes, already under way, are not effectively retarded even at the lowest temperatures at which the fruit was stored. The color was also best at the lowest temperature. It was observed, furthermore, that grade C fruit, practically fully processed and with a very small proportion of rag at the shoulder, held at 10°, remained in better condition after thawing than the same grade of fruit after storing at temperatures of 27° to 40°. Much work remains to be done to demonstrate that there is any material advantage, so far as practical packing-house management is concerned, in holding fruit in a frozen condition rather than in commercial storage at about 32°.

TABLE 8.—Effect of low-temperature storage on the quality of Deglet Noor dates

Grade ¹	Time of picking	Before storage		After 4 months' storage						After holding 1 additional month at 60°-70° F.					
		Moisture	Proportion of rag at shoulder	Storage temperature	Moisture	Reducing sugar ²	Proportion of rag at shoulder	Color	Flavor	Moisture	Reducing sugar ²	Proportion of rag at shoulder	Color	Flavor	
	1927	P.ct.		° F.	P.ct.	P.ct.					P.ct.	P.ct.			
B-----	Oct. 11	19.65	½	40	19.52	24.23	½-¾	Russet	Full	18.57	28.91	½	Russet	Full.	
				32	19.97	25.92	½	do	do	19.83	28.67	½	do	Do.	
				32	20.50	26.31	0-¼	do	Slight.	17.78	27.40	0-¼	Chestnut	Slight.	
C-----	do	19.41	0-¼	27	19.40	28.88	0-¼	do	Full	17.23	29.15	0-¼	do	Do.	
				10	19.93	27.40	0-¼	do	do	18.81	27.98	¼	Russet	Full.	
D-----	do	21.46	0	32			0	Chestnut	None						
				10			0	do	do						
B-----	Nov. 10	23.98	½	40	22.00	24.84	½	Russet	Full	19.04	27.43	½	Russet	Full.	
				32	22.92	25.39	½	do	do	22.69	29.50	½	Chestnut	Do.	
				32	21.93	22.18	½	Chestnut	do	21.29	30.86	¼	Chestnut	Slight.	
C-----	do	23.30	¼-½	27	23.90	26.53	½	do	do	17.66	26.57	¼	do	Do.	
				10	23.18	22.80	½	Russet	do	18.78	27.13	¼	Russet	Full.	
D-----	do	23.33	0	32			½	Chestnut	None				do	Do.	
				10			0	Russet	Slight						

¹According to Table 5 and Plate 2.

²Sugar percentages calculated on moisture-free basis in all cases.

SUMMARY

The Deglet Noor date is a choice variety grown extensively in the Coachella Valley, Calif. The rapid annual increase in its production makes it desirable that a portion of the crop be placed in storage during harvest and marketed later. This will assure better returns to the grower and relieve the demand for labor and space in the packing houses which results when the entire crop is packed and marketed during the comparatively short harvest period.

The experiments here recorded were undertaken to observe and study some of the physical and chemical changes that occur in this date as it ripens on the tree and to observe certain conditions of artificial maturation or processing while the fruit is held in storage at different temperatures.

The Deglet Noor is a cane-sugar date, and only small quantities of reducing sugar resulting from the inversion of cane sugar are present as the fruit matures. This inversion, however, continues steadily, as the fruit remains on the tree and is accelerated or retarded according to seasonal conditions. Fruit maturing late in the season contains relatively less reducing sugar than fruit maturing earlier, before the high temperature prevailing during the summer has moderated. The moisture content of the dates is influenced by rain and by irrigation and on the whole appears to be lower in the late-maturing than in the early-maturing fruit.

The normal changes that take place in the Deglet Noor date as it ripens on the tree include: (1) A change in the skin color from rose or deep pink to cinnamon or hazel; (2) a gradual softening of the flesh, starting at the tip and progressing from the skin toward the seed; (3) elimination of the astringency by the deposition of the tannin in an insoluble, tasteless form; (4) inversion of cane sugar in the softened flesh. These changes, in a general way, are hastened by heat and retarded by cold. If the temperature is sufficiently high they continue rapidly until the fruit loses its flavor, acquires a mahogany color, and becomes sirupy through excessive inversion of cane sugar.

Fairly immature fruit may be successfully ripened by artificial processing, but the conditions required depend definitely on the relative stage of maturity of the fruit. Careful grading of the fruit on this basis before processing is a practicable packing-house procedure. Processing at temperatures above 100° F. result in rapid deterioration of the fruit, but a considerable proportion of the fruit taken from the tree according to the picking methods now in use may be processed and conditioned at 95° or less to produce the desired color and texture without loss of flavor and excessive inversion of cane sugar. If the reducing-sugar content is kept below 25 per cent and the moisture is reduced to about 25 per cent, the fruit is attractive in appearance, of normal flavor, and will not sour nor become sirupy.

The effect of storing processed dates of various grades and unprocessed dates of varying stages of maturity at 32°, 50° to 60°, and 60° to 70° F., in bulk and in packages, was studied. Under these storage conditions the inversion of cane sugar progresses according to the temperature. At 32° it is very slight, but at the higher temperatures it is sufficient to make the fruit sirupy in a few months.

Partially mature fruit and that partially processed may be successfully stored at 32° for 9 or 10 months, whereas the more mature or more fully processed fruit will remain in good condition for only 5 or 6 months. At the higher temperatures none of the fruit retains its quality for more than a short period. The presence of a light brownish purple colored ring at the stem end is an aid in determining the long-storage quality of the fruit.

The experiments on the effect of pasteurizing the fruit were inconclusive. Storage at temperatures sufficiently low to freeze the dates solid appears to have practical possibilities, especially in connection with the more mature grades of fruit. It seems doubtful, however, whether such a procedure has any decided advantage in handling slightly immature fruit which can be successfully stored at 32° F.

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